THE EFFECT OF VIOLENT EXERCISE ON TISSUE GLYCOGEN IN ALBINO MICE*

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INTRODUCTION

A number of studies have shown that the swimming capacity of small laboratory animals is modified by various internal and external factors (1, 2, 3, 6). Glycogen is the ready source of energy in exercising mammals. It therefore seemed worth-while to ascertain the effect of prolonged forced swimming on the glycogen content of various tissues in the albino mouse. (6)

MATERIALS AND METHODS

Albino mice weighing between 30 and 40 (mean, 33 grams) grams were obtained from the colony maintained at the Army Chemical Center, Maryland. They were housed and cared for in the animal facility at the Armed Forces Institute of Pathology until used. Four individuals were used for each test run.

Mice were forced to swim to exhaustion in water baths held at 25°C and 35°C, respectively. A wetting agent was added to the water to decrease the bouyancy attributable to the fur. Total swimming time for each mouse was recorded. Immediately thereafter, the animal was decapitated. Liver, kidneys, brain, and leg muscle were removed and fixed in either neutral formalin, absolute alcohol, or liquid nitrogen. The latter were dehydrated *in vacuo* imbedded in

paraffin and later sectioned for histochemical demonstration of glycogen (PAS). Tissues from exhausted mice were compared with controls which had not been forced to swim.

A second series of swimming experiments was performed; samples of blood were taken for lactic acid estimations; samples of leg muscle and liver were taken for microchemical analysis for glycogen content. (4) Results from resting controls were compared with those from exhausted mice.

RESULTS

Histochemical. The prepared slides from experimentals and controls were examined under the light microscope. In general, it was impossible to distinguish the experimentals from the controls--either with respect to H-E staining characteristics or with respect to location or amount of histochemically demonstrable glycogen. Skeletal muscle showed some changes. Muscle from the exhausted mice showed alternate fibers which lacked PAS visible glycogen. The difficulty of evaluating this is obvious.

Microchemical. Table 1 gives the average values for carbohydrate content of various tissues in mice forced to swim. It is evident that swimming time is prolonged in warm

water, and that blood lactic acid increases during forced swimming; whereas liver glycogen decreases markedly as does muscle glycogen.

DISCUSSION

Correlation and regression coefficients were calculated for the different variables. It was possible to fit the data to a general straight line.

$$y = a + bx$$

The relationships of the different variables with the respective coefficients of correlation (r) are shown below:

Swimming Time = 16.7·bath temperature - 388;

$r = 0.99$

Liver glycogen, % = 6.5 - 0.19·bath temperature;

$r = 0.85$

Liver glycogen, % = 0.34·body weight - 10;

$r = 0.77$

Muscle glycogen, % = 0.11·liver glycogen - 0.05;

$r = 0.60$

Liver glycogen, % = 2.1 - 0.01·swim time; $r = 0.89$

Muscle glycogen drops sharply during the first twenty minutes of swimming at any temperature. Thereafter, it levels off and shows no further measurable change. Blood lactic acid

rises sharply during the first twenty minutes of swimming at any temperature and then "cycles" above and below the control average for the remainder of the swimming time.

It is interesting to note that the amount of muscle glycogen is not correlated very well with swimming time ($r = 0.08$). Apparently, muscle glycogen in the active mouse is held at a steady level during exercise. The liver serves as the glycogen supply depot. When the liver glycogen is exhausted the mouse can no longer swim.

These results are essentially in accord with previous work on guinea pigs in which larger animals have a greater percentage of liver glycogen and in which a clear negative correlation exists between swimming time and liver glycogen content (5).

SUMMARY

Albino mice were forced to swim to exhaustion in water baths of different temperatures. Histochemical and microchemical analyses of various tissues from exercised and control mice were made. There was found a positive correlation between the following: Bath temperature and swimming time; liver glycogen and body weight; muscle and liver glycogen. Negative correlations were found between liver glycogen and bath temperature, liver

glycogen and swimming time. Muscle glycogen is held relatively constant after the first twenty minutes of swimming.

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TABLE 1

Effect of forced swimming on glycogen and lactic acid content of some tissues from albino mice. Mean value. N = 4.

Bath T, °C	Swim Time Minutes	Blood Lactic Acid mg/100 ml	Glycogen, %	
			Liver	Muscle
Control	Rested	24	2.2	0.16
25	28	39	1.5	0.06
35	180	32	0.1	0.07

FOOTNOTE

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STATEMENT OF COMMITMENT AND POLICY

All research done in these laboratories, in connection with the present project and all other projects which involve the use of animals, was carried out in strict accord with the letter and spirit of the following principles.

GUIDING PRINCIPLES IN THE CARE AND USE OF ANIMALS

(Approved by the Council of
The American Physiological Society)

Only animals that are lawfully acquired shall be used in this laboratory, and their retention and use shall be in every case in strict compliance with state and local laws and regulations.

Animals in the laboratory must receive every consideration for their bodily comfort; they must be kindly treated, properly fed, and their surroundings kept in a sanitary condition.

Appropriate anesthetics must be used to eliminate sensibility to pain during operative procedures. Where recovery from anesthesia is necessary during the study, acceptable technic to minimize pain must be followed. Curarizing agents are not anesthetics. Where the study does not require recovery from anesthesia, the animal must be killed in a humane manner at the conclusion of the observations.

The postoperative care of animals shall be such as to minimize discomfort and pain, and in any case shall be equivalent to accepted practices in schools of Veterinary Medicine.

When animals are used by students for their education or the advancement of science such work shall be under the direct supervision of an experienced teacher or investigator. The rules for the care of such animals must be the same as for animals used for research.

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